

Optical nonlinearities between glass and Liquid Crystal

J. A. Martín-Pereda

E.T.S.I. de Telecomunicación (UPM), Ciudad Universitaria
28040 Madrid, Spain

Abstract

The nonlinear optical properties of the interface between glass and liquid crystal are reported. Switching characteristics and optical hysteresis have been studied.

Introduction

In this paper, a study of the behaviour of a non-linear interface is reported. The interface taken has been between an ordinary dielectric and a dielectric material with an intensity-dependent index of refraction, namely, a liquid crystal of the nematic type. This medium has a very large effective non linear experiments. Its response time is too slow (10ms) to be useful in practical systems, but it is very useful to study this type of non linear effects.

The basis of the experiments are the previous studies¹⁻² that have shown that the intensity-dependent refractive index associated with optically induced molecular reorientation in a typical nematic crystal, such as n(p-methoxy benzylidene)-p-butyl aniline (MBBA), is extremely large. Third-order non linear optical processes are easily observable with lasers of moderate power (intensity of the order of 10 W/cm²). A multiplying pattern of laser diffraction from a nematic film has been reported. The phenomenon is shown to be the result of spatial self-phase modulation that is due to the laser-induced Fredericksz transition. This effect can be employed for studies of nonlinear interfaces.

The interest of nonlinear interfaces is because they are potentially useful as very fast optical switches and logic elements³. Previous theoretical studies performed by several groups have shown the possibility to obtain switching times smaller than picoseconds. Initial plane wave theories of nonlinear interfaces predicted⁴ that the reflectivity of the interface is unity at low intensities and for intensities above a threshold value the reflectivity will switch to a lower value. Some difficulties arise from the fact due to the gaussian profile of the light beam. Several new results appear when this type of profile is taken into consideration⁴. And these results have not been predicted with plane wave theories. A theory with a two-dimensional Gaussian beam has been developed and some experiments are in a good agreement with such a theory⁵. Moreover, no optical bistability has been obtained.

Experimental

The experiments were performed with the set-up shown in Fig.1. The input 5145 Å beam from an argon ion laser was focused to a $1/e$ amplitude radius of $\omega_0 = 100 \mu$ the interface. This corresponds to a far field diffraction angle of $\psi_0 = 0.09^\circ$. The linear medium was an optically polished prism with $n = 1.61$. The nonlinear medium, MBBA, has as refractive indexes $n_o = 1.54$ and $n_e = 1.74$. The change with temperature is given in the literature. The scattering loss in the interaction region along the interface was ~ 50 percent. Homeotropic and homogeneous molecular alignment have been taken. Some different behaviour were obtained in both cases. Light intensity was taken by a calibrated photodiode.

Fig.2 shows a plot of the low intensity reflectivity of the interface as a function of angle ψ (Fig.1). The critical angle has a value of 17° at the studied case. As the intensity of the input beam is increased, the evanescent field in the nonlinear medium will act to reorient the molecules director to point along the laser polarization direction. Hence, the refractive index difference will be lowered and the interface will become partially transmitting. The difference between these two situations is shown in Fig.3 where the ray paths inside the prism and the nonlinear medium have been plotted.

The obtained results at higher incident light intensities are shown in Fig.4. The experimental measurements of reflectivity as a function of incident intensity, for the case $\psi = 20^\circ$, are shown. These results clearly display a second jump in reflectivity and even a smooth third jump, results not predicted by plane-wave theories. This second jump was predicted by two-dimensional Gaussian beam theories.

If reflected power is plotted versus incident power for $\Psi = \Psi_c$, (Fig.5), with an scan time of 30 s. an hysteresis behavior was obtained. As it can be seen, the two branches have different senses as the ones obtained by Smith and Tomlinson with a suspension of dielectric particles⁵.

Fig.6-9 show the different output beams for different incident light intensities. As it can be seen, the transmitted beam shows the well-known multiple-ring diffraction pattern.

The experiments have permitted to confirm, with a different experimental set up, the main predictions of previous numerical analysis of the behaviour of a nonlinear interface with an incident Gaussian light beam. Moreover, because the very complicated behavior of liquid crystals, some new effects are likely to occur, the simple way of changing refractive index in non linear materials cannot be applied here. Hence some more experimental work and some variations in the theory must be done to understand the above described phenomenon.

I would like to thank Dr. Muriel for many illuminating discussions on the experimental set up and R. Beltrán and P. Menéndez-Valdés for their help in taking data.

This work was supported by the Spanish Comisión Asesora de Investigación Científica y Técnica (Grant n.).

References

1. Martín-Pereda, J.A. and López F.J., *Optics Letters*, **7**, 590, 1982.
2. Martín-Pereda, J.A., López, F.J. and Muriel, M.A., *Mol. Cryst. Liq. Cryst.* **99**, 1, 1983.
3. Smith, P. and Tomlinson W.J., *IEEE Spectrum*, **26**, June, 1981.
4. Kaplan, P.E., *Sov. Phys. JETP* **45**, 896, 1977.
5. Smith, P.W., Tomlinson, W.J., *IEEE J. of Q.E.*, **17**, 340, 1981.
Smith, P.W., Tomlinson, W.J., *IEEE J. of Q.E.*, **20**, 30, 1984.

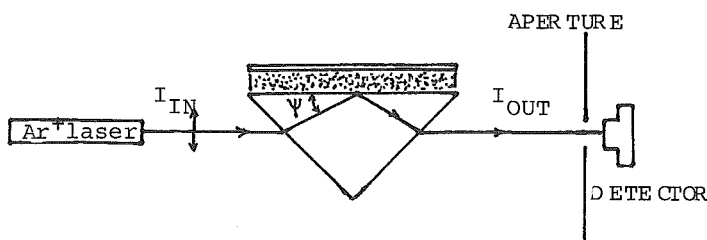


Figure 1

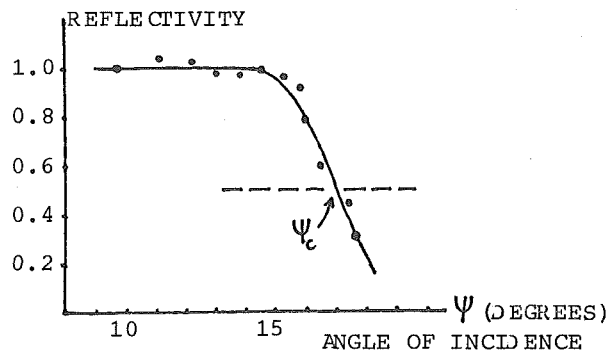


Figure 2

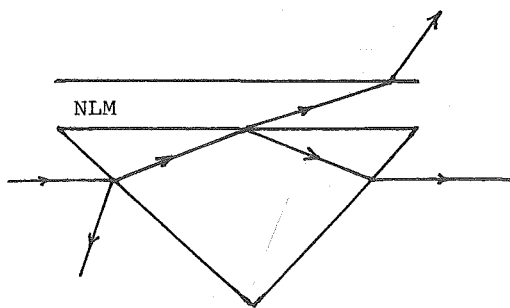


Figure 3

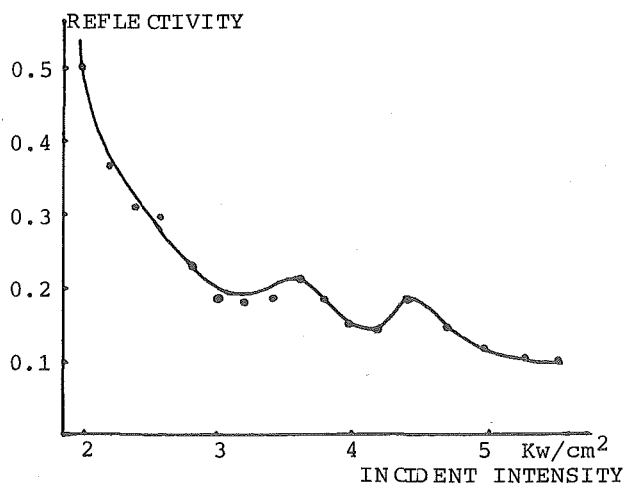


Figure 4

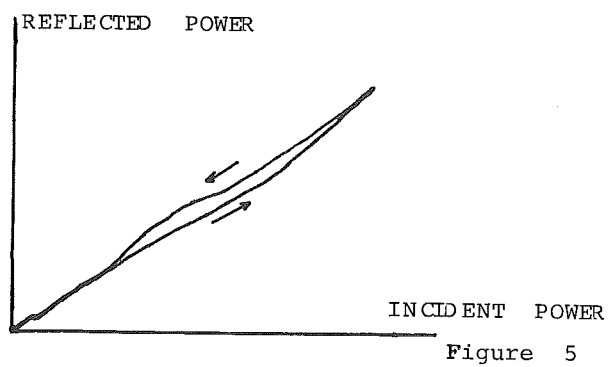


Figure 5

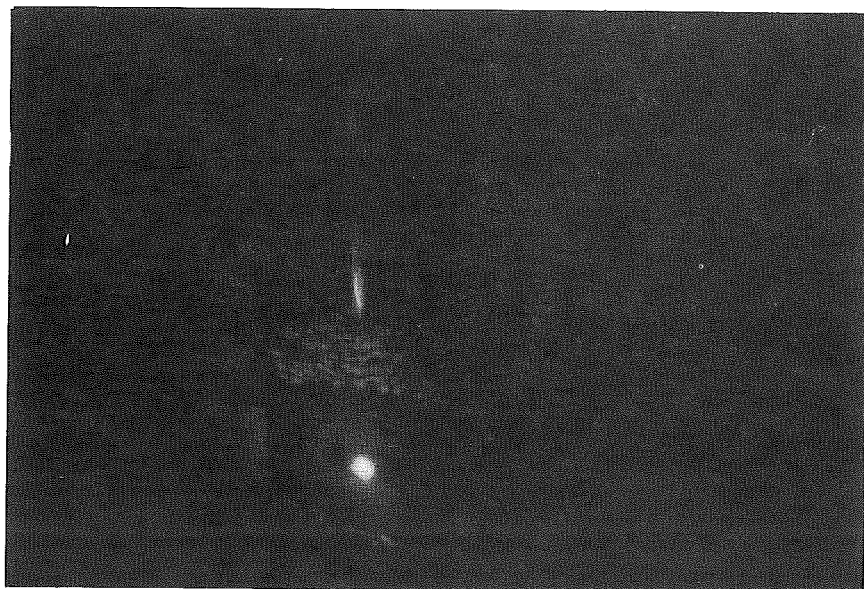


Figure 6

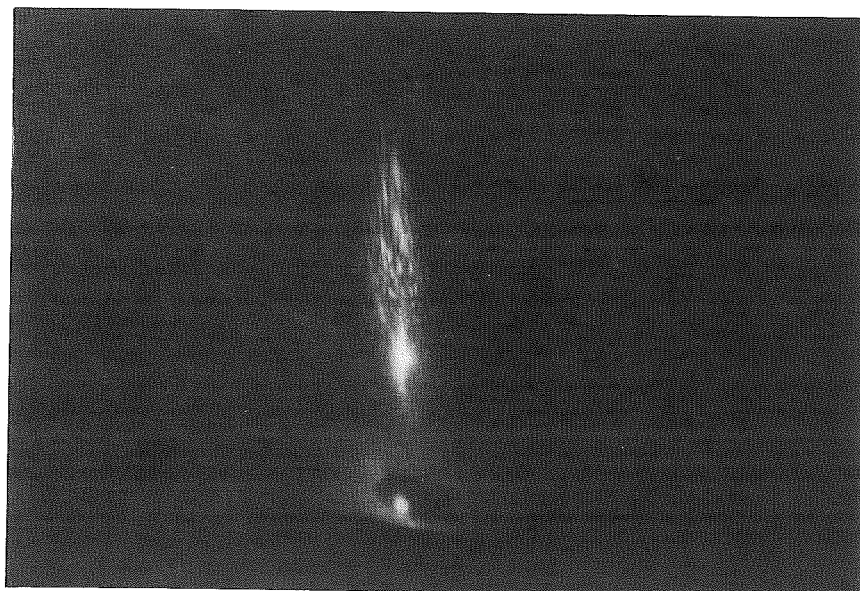


Figure 7

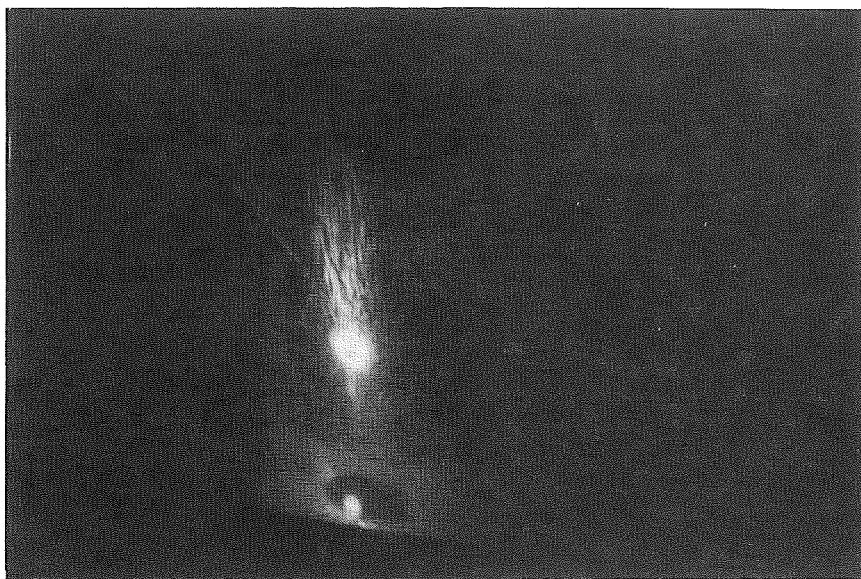


Figure 8



Figure 9